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(NASA-CR-151156) ORBITER KU-BAND TRANSMITTER Final Report (Motorola, Inc.) 49 p HC A03/MF A01 CSCL 17B

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PIA 2216

FINAL REPORT
FOR
ORBITER KU-BAND TRANSMITTER

Submitted to
NASA Lyndon B. Johnson Space Center

Contract No.
NAS 9-14942

November 30, 1976

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MOTOROLA · Government Electronics Division • 8201 E McDOWELL ROAD, SCOTTSDALE, ARIZ 85252

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1.0 INTRODUCTION

1.1 Scope of Report

The scope of this report is to summarize the work completed on Contract No. NAS 9-14942 by Motorola Inc., Government Electronics Division for NASA, Lyndon B. Johnson Space Center. The report will discuss the equipment that was designed and built, the equipment performance, and any problem or potential problem areas. Included as an appendix is the Acceptance Test Procedure and Data that was performed on the unit November 3, 1976.

1.2 Purpose of Contract

The purpose of this contract was to design, build, and test an engineering breadboard Ku-Band Quadraphase Shift Keyed (QPSK) and wideband Frequency Modulated (FM) transmitter. This Orbiter Ku-Band Transmitter drawer is to simulate the Orbiter Transmitter and meet the functional requirements of the Orbiter communication link.

2.0 SUMMARY OF COMPLETED WORK

2.1 General

Item 1 of the contract, the Orbiter Ku-Band QPSK and wide-band FM Transmitter, and item 2, the data, per the contract Data Requirements List (DRL), have been completed. The end product hardware was tested at Motorola and accepted by the NASA Technical Monitor on November 4, 1976.

Throughout the contract effort, the data items were submitted to NASA, JSC, as required. During the design phase, a Preliminary and Critical Design Review was held at Motorola. Data packages were submitted in conjunction with the reviews. Engineering Drawings were submitted when the hardware was completed and a copy of each drawing is included in the Maintenance and Operation Manual. The Acceptance Test Plan and Acceptance Test Procedure were submitted and, after the Acceptance Test, the test data was also submitted. With the submittal of the Maintenance and Operation Manual and this Final Report, the data requirements of the contract are satisfied.

2.2 Equipment Description

The Orbiter Ku-Band Transmitter, Motorola Part No. 01-P07000K, is an engineering breadboard transmitter simulator contained in a single drawer suitable for mounting in a standard test cabinet. For a complete description of the transmitter and its electrical characteristics refer to the Maintenance and Operation Manual.

The equipment was assembled by qualified assembly operators and at various points throughout the assembly the equipment was inspected by Quality Assurance inspectors. Each module

2.2 Equipment Description (Contd)

or subassembly was tested prior to system assembly. During the design phase, a stress analysis was performed on the modules in order to detect and correct any over-stressed component which might degrade the reliability of the equipment.

Upon completion of the transmitter assembly, the equipment was successfully tested according to the Acceptance Test Procedure and accepted by the NASA Technical Monitor.

2.3 Equipment Performance

The Transmitter was tested according to the Acceptance Test Procedure (12-P07001K) to verify proper operation and compliance with the technical requirements of the contract as specified in the Statement of Work. The performance is summarized in the ATP data which, along with the test procedure, is included in the appendix.

The Acceptance Test, as witnessed by the NASA Technical Monitor, was performed November 1-3, 1976 at Motorola. During the testing, it was noticed that the QPSK spectrum was not perfectly symmetrical at the higher data rates. It was thought that the problem might be corrected by adjusting the quadrature of the Mode 1 Modulator and therefore the top cover was removed to expose the Mode 1 Modulator for retuning. The quadrature was adjusted and the cover replaced. For further discussion refer to section 3.2. After the adjustment, the parameters which might have been affected were retested on November 3, 1976. The retest data is attached to the end of the ATP and is part of the Acceptance Test Data.

Where there were contract specifications, test limits were established to which the test data was compared. Where there were no specifications, the test data was recorded for

2.3 Equipment Performance (Contd)

information only. As shown by the Acceptance Test Data, the Transmitter meets all the requirements as specified in the Statement of Work of the contract.

3.0 PROBLEM AREAS

3.1 Specification Noncompliances

The Orbiter Ku-Band Transmitter complies with all specifications of the contract Statement of Work and all agreements as documented in the minutes of the Preliminary Design Review of April 22, 1976, and the Critical Design Review of July 12, 1976.

3.2 Other Equipment Characteristics and Recommendations

Although the Transmitter complies with all the specifications, there are three areas, not specified in the contract, where the performance is further described. The three areas are listed below along with any recommendations.

The first condition is a minor nonsymmetry in the spectrum of the QPSK modulation. The nonsymmetry is noticeable at the output of the Mode 1 Modulator. The nonsymmetry between the upper and lower J1 modulation terms is negligible at data rates up to 20 Mbps. At the highest data rate of 100 Mbps the nonsymmetry is approximately 2.6 dB. The nonsymmetry appears to be caused by frequency roll off of the upper J1 terms at the higher data rates. Preliminary testing between the transmitter and the TDRS simulator has not indicated any significant performance degradation at the higher data rates. Although this performance is not as desired, it is believed that this will not significantly degrade the system performance. Therefore, it is recommended that the Transmitter be left as is unless serious degradation occurs. To correct this problem, the Mode 1 Modulator would probably need to be redesigned using higher frequency components.

Another characteristic of the Mode 1 Modulator is the change in incidental AM of the output waveform with the change of power unbalance. The incidental AM is difficult to observe at the output but can be seen at the Mode 1 Modulator output on a high frequency sampling oscilloscope. The amount of AM at the Mode 1 Modulator output is not the same as at the Transmitter output since there is limiting which occurs after the Mode 1 Modulator. The AM has been adjusted for minimum at an 80/20 power unbalance and it increases to about 8% at 50/50 at the module output. The minimum was set at an 80/20 unbalance since that is the normal power unbalance setting. It is not known whether the incidental AM will cause system performance degradation. Therefore, it is recommended that the Transmitter be left as is unless serious degradation occurs. To correct the problem would probably require redesigning the Mode 1 Modulator to eliminate possible circulating ground currents.

The third condition involves modulation input compatibility for the d2 and d3 inputs. The levels, as summarized in the Preliminary Design Review data package, were to be TTL levels (0-5 volts nominal). The actual operation requires input levels of 0 to +0.8 volts for a logic "0" level and a minimum of +4.0 volts for a logic "1" level. The logic "0" voltages are TTL compatible. The logic "1" voltages are not strictly TTL compatible. Technically, logic "1" voltages can be as low as +2.4 volts. If the voltage drops below +4.0 volts, modulation degradation will occur as evidenced by reduced carrier suppression. If the input voltages cannot be maintained at greater than +4.0 volts, then the input transistor stages for these data inputs can be redesigned to accommodate the desired voltage levels.

4.0 CONCLUSIONS

As demonstrated by the Acceptance Test, the Orbiter Ku-Band Transmitter meets the requirements of the contract as specified in the Statement of Work. There are three areas where the performance is less than desired though adequate. These items along with recommendations were discussed in section 3.0, Problem Areas. It is believed that this transmitter simulator meets the functional requirements of the Orbiter communication link as defined in the contract and understood by Motorola.

As a result of delivering item 1, the transmitter hardware, and item 2, the data, the contract has been successfully completed.

APPENDIX

Acceptance Test Procedure and Data
for Orbiter Ku-Band Transmitter

* APPLICATION		REVISIONS			
NEXT ASSEMBLY	USED ON	LTR	DESCRIPTION	DATE	APPROVED

ASTERISK INDICATES DATA WHICH IS NONMANDATORY - FOR INFORMATION ONLY.

TEST DATA APPROVED BY:

Ron Halterman 11-3-76

Meredith Hamilton 11-3-76

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	MFG	PROJ NO. 2216	ACCEPTANCE TEST PROCEDURE FOR ORBITER KU-BAND TRANSMITTER
MATERIAL:	CONTR NO. NAS 9-14942		
	RELEASE NOTICE		
	APPROVED R. Halterman	DATE 9/28/76	SIZE A — CODE IDENT NO. 94990 — DWG. NO. 12-P07001K
	APPROVED J. R. Ahearn	DATE 9/30/76	SCALE — SHEET 1 OF 37

1.0 SCOPE

This document establishes the acceptance test procedure and test limits for the Orbiter Ku-Band Transmitter, Motorola Part No. 01-P07000K of contract NAS 9-14942.

2.0 APPLICABLE DOCUMENTS

The following documents are applicable to the Orbiter Ku-Band Transmitter and form a part of this document to the extent specified herein.

Document	Title
Exhibit A of Contract NAS 9-14942	Statement of Work for Orbiter Ku-Band Transmitter
70-P06928K	Orbiter Ku-Band Transmitter Outline Drawing

3.0 TEST EQUIPMENT REQUIRED

The test equipment listed or its equivalent will be required to perform this test. The equipment used shall have a current calibration sticker where required.

QTY	EQUIPMENT	MANUFACTURER/MODEL
1	AM-FM Signal Generator	HP 8640B opt. 002
1	Test Oscillator	HP 651B
1	Signal Generator	HP 626A
1	Signal Generator	HP 608C
2	Pulse Generator	Data Dynamics 5113
1	Pulse Generator	EH 122
2	RMS Voltmeter	HP 3400
1	Power Meter	HP 435A
1	Power Sensor	HP 8481A
1	Spectrum Analyzer	HP 141T
1	Analyzer, RF Tuning Section	HP 8555A
1	Analyzer, IF Section	HP 8552B
1	Analyzer, Tuning Section	HP 8553B
1	Frequency Counter	EIP 351D
1	Vector Impedance Meter	HP 4815A
1	Crystal Detector	HP 8470B
1	Digital Multimeter	Fluke 8600A
1	Oscilloscope	HP 1710
1	2 GHz High Pass Filter	Microlab FH 2000
1	Waveguide to SMA Adapter	OSM 20187 AJ
1	FM Demodulator	Motorola 01-P05461J
1	Variable Attenuator	HP P382A

4.0 GENERAL

4.1 PURPOSE OF TEST

The purpose of this transmitter acceptance test is to verify proper operation and conformance with the technical requirements of the contract as specified in the Statement of Work, Exhibit A. The parameters tested or calculated will be recorded and compared with the test limits on the data sheets where specified in the Statement of Work. In addition, there will be performance and capability tests for information only with no test limits.

4.2 TEST CONDITIONS

The tests shall be performed under normal ambient conditions with the transmitter operating on the bench. There shall be a minimum of one hour warm-up for the transmitter and test equipment prior to testing.

4.3 TEST SEQUENCE

The tests contained herein may be performed in any sequence.

4.4 STANDARD OPERATION AND SETTINGS

Unless otherwise specified, the following standard settings and operation shall be used:

Ku-Band Frequency - 15.0085 GHz
Subcarrier Frequency - 8.5 MHz
Subcarrier Power Unbalance - 80/20(6dB difference)
Mode 1 Power Unbalance - 80/20(6dB difference)
Subcarrier Level - 0.25 VRMS (50 Ω)
d1 Modulation - 50 MHz square-wave, ECL levels, -.9 and -1.8 volts nominal

4.4 (Continued)

d2 Modulation - 192 KHz square-wave, TTL levels,
0 and 5 volts nominal

d3 Modulation - 2 MHz square-wave, TTL levels,
0 and 5 volts nominal

Video Modulation - 4.2 MHz sine-wave, 0.40 VRMS(50 Ω)

Select Subcarrier On if either Mode 1B or 2 is selected.

5.0 ELECTRICAL TESTS

5.1 Frequency and Stability

5.1.1 Connect the equipment as shown in Figure 1. With no modulation present, measure and record the minimum and maximum frequency by adjusting the Frequency Adjust control.

5.1.2 Adjust the frequency for 15.0085 GHz. Select Mode 1 and record the frequency. Select Mode 2 and record the frequency.

5.1.3 After one hour has elapsed since paragraph 5.1.2, select Mode 1 and measure and record the frequency. Select Mode 2 and measure and record the frequency. Do not adjust the frequency between the test of 5.1.2 and 5.1.3.

5.2 RF Bandwidth

5.2.1 Connect the equipment as shown in Figure 1. Apply a signal of +2 dBm at 488.5 MHz to the 488.5 MHz IN connector. Measure the Ku-Band output power. Vary the frequency on both sides of 488.5 MHz and measure and record the frequency difference where the response is down 1dB. Repeat for the 3dB response. Calculate the bandwidths.

5.3 Output Power

5.3.1 Connect the equipment as shown in Figure 1 . Select Mode 1A. With no modulation measure and record the output power.

5.3.2 Select Mode 1A. Modulate d1 and d3 with the standard conditions. Measure and record the output power.

5.3.3 Select Mode 1B and Subcarrier On. Modulate d1, d2, and d3 with the standard conditions. Measure and record the output power.

5.3.4 Select Mode 2 and Subcarrier Off. With no modulation measure and record the output power.

5.3.5 Select Mode 2 and Subcarrier On. Modulate d2, d3, and video with the standard conditions. Measure and record the output power.

5.4 FM Frequency Response

5.4.1 Connect the equipment as shown in Figure 2 . Select Mode 2 and Subcarrier Off. Apply a 500 KHz sine-wave of approximately 400 mv RMS to the video input. Measure and record the demodulator baseband output level in dB. While keeping the input level constant, vary the frequency and measure and record the response.

5.4.2 Apply a 10 MHz sine-wave of approximately 250 mv RMS to the Subcarrier Input. Measure and record the frequency response of the Subcarrier Input.

5.5 FM Deviation Sensitivity

5.5.1 Connect the equipment as shown in Figure 3 . Select Mode 2 and Subcarrier OFF. Apply a 500 KHz sine-wave to the Video input. Adjust the signal level for 2.405 radians (first carrier null). Measure and record the input voltage and calculate the deviation sensitivity.

$$\text{SENSITIVITY(MHz/v)} = \frac{1.202\ \text{MHz}}{\text{input voltage(RMS)}} \times \frac{.707\ \text{RMS}}{\text{PK}} = \frac{.850}{\text{Vin(RMS)}}$$

5.5.2 Repeat 5.5.1 applying an 8.50 MHz sinewave to the QPSK Subcarrier input. Adjust the signal level for 1.202 radians (first carrier null of the second harmonic at 977 MHz.)

$$\text{SENSITIVITY(MHz/v)} = \frac{7.22}{\text{Vin(RMS)}}$$

5.5.3 Apply a DC voltage to the Video input. Verify that a positive voltage increases the frequency. Verify that the carrier frequency can be deviated at least plus and minus 20 MHz.

5.6 FM Deviation Linearity

5.6.1 Connect the equipment as shown in Figure 2 . Select Mode 2 and Subcarrier Off. Apply a DC voltage to the Video input. Measure and record the output frequency for the given input voltages. Calculate the frequency change for each voltage step and calculate the DC linearity.

$$\%\ \text{LINEARITY} = \frac{\Delta f\ \text{max} - \Delta f\ \text{min}}{\Delta f\ \text{max} + \Delta f\ \text{min}} \times 100$$

5.6.2 Apply a 4.0 MHz sine-wave to the Video input. Measure and record the input voltage and the Demodulator output voltage. Calculate the total system sensitivity (S) for each level and from that calculate the deviation linearity.

$$S = \frac{\text{Vout (demod out)}}{\text{Vin (video in)}}$$

$$\% \text{ LINEARITY} = \frac{\text{S max} - \text{S min}}{\text{S max} + \text{S min}} \times 100$$

5.6.3 Apply a ~~10~~ 8.5 RH MHz sine-wave to the QPSK Subcarrier input. Repeat 5.6.2.

5.7 <u>FM Harmonic Distortion</u>

5.7.1 Connect the equipment as shown in Figure 2. Select Mode 2 and Subcarrier Off. Apply a 4.0 MHz sinewave of 0.40 VRMS to the Video input. Look at the demodulated output on the spectrum analyzer and measure and record the relative level of the harmonics. Calculate the harmonic distortion.

$$\% \text{ DISTORTION} = \sqrt{\sum \left(\frac{V_n}{V_1}\right)^2} \times 100$$

$$\frac{V_n}{V_1} = 10\exp\left[\frac{\text{relative level (-dB)}}{20}\right]$$

V_1 = level of fundamental V_n = level of n^{th} harmonic

5.7.2 Repeat 5.7.1 applying a ~~10~~ 8.5 RH MHz sinewave of ~~0.45~~ 0.30 RH VRMS to the QPSK Subcarrier input.

5.8 Subcarrier Frequency

5.8.1 Connect the equipment as shown in Figure 4 . Select the Subcarrier On. Monitor the QPSK Subcarrier Out and measure and record the QPSK Subcarrier frequency for each setting of the Subcarrier Frequency Select Switch.

5.9 Subcarrier Data Rate and Deviation

5.9.1 Connect the equipment as shown in Figure 5 . Select Mode 2, Subcarrier On, and 8.5 MHz. Adjust the Subcarrier Level for 0.25 VRMS which is about 6 MHz peak deviation. Apply standard modulation to the d2 and d3 inputs.

5.9.2 Observe the demodulated output on the spectrum analyzer. Adjust the Subcarrier Unbalance for 50/50 (equal d2 and d3 J1 sidebands). Adjust the square-wave modulation for best symmetry and carrier null. Measure and record the level of the carrier and the J1 sidebands relative to the level of the unmodulated carrier.

5.9.3 Repeat 5.9.2 with a 16 KHz square-wave for d3 and a 96 KHz square-wave for d2.

5.10 Subcarrier Power Unbalance

5.10.1 Connect the equipment as shown in Figure 5 . Select Mode 2, Subcarrier On, and 8.5 MHz. Adjust the Subcarrier level for 0.25 VRMS which is about 6 MHz peak deviation. Apply standard modulation to the d2 and d3 inputs.

5.10.2 Observe the demodulated output on the spectrum analyzer. While observing the J1 sidebands, adjust the Subcarrier Unbalance for 50/50 (equal J1 sidebands). Record if a 50/50 balance is achieved.

5.10.3 Adjust the Subcarrier Unbalance for 90/10 (the d3 sidebands 9.5 dB above the d2 sidebands). Record if a 90/10 unbalance is achieved.

5.10.4 Adjust the Subcarrier Unbalance for 80/20 with standard modulation. Adjust the square-wave modulation for best symmetry and carrier null. Measure and record the level of the J1 sidebands and carrier relative to the unmodulat ed carrier.

5.11 Incidental AM

5.11.1 Connect the equipment as shown in Figure 6 . Select Mode 2, Subcarrier On, and 8.5 MHz. Apply standard video modulation and standard subcarrier level.

5.11.2 Measure and record the DC voltage out of the crystal detector. Measure and record the AC voltage peak to peak on the oscilloscope and calculate to incidental AM.

$$\% \text{ AM} = \frac{\text{AC voltage (pk-pk)}}{\text{DC voltage x 2}} \quad \text{x } 100$$

5.12 <u>QPSK Data Rate and Deviation</u>

5.12.1 Connect the equipment as shown in Figure 1 . Select Mode 1, Mode 1A, and Subcarrier Off. Apply standard modulation to the d1 and d3 inputs.

5.12.2 Observe the output on the spectrum analyzer. Adjust the Mode 1 Unbalance for 50/50. Adjust the square-wave modulation for best symmetry and carrier null. Measure and record the level of the carrier and the J1 sidebands relative to the level of the unmodulated carrier.

5.12.3 Repeat 5.12.2 with a 4 MHz square-wave for d1 and a 16 KHz square-wave for d3.

5.13 <u>QPSK Power Unbalance</u>

5.13.1 Connect the equipment as shown in Figure 1 . Select Mode 1, Mode 1A, and Subcarrier Off. Apply standard modulation to the d1 and d3 inputs.

5.13.2 Observe the output on the spectrum analyzer. While observing the J1 sidebands, adjust the power unbalance for 50/50 (equal d1 and d3 sidebands). Record if a 50/50 balance is achieved.

5.13.3 Adjust the power unbalance for 90/10 (the d1 sidebands 9.5 dB above the d3 sidebands). Record if a 90/10 unbalance is achieved.

5.13.4 Adjust the power unbalance for 80/20 with standard modulation. Adjust the square-wave modulation for best symmetry and carrier null. Measure and record the level of the J1 sidebands and carrier relative to the unmodulated carrier.

5.14 Dual QPSK Operation

5.14.1 Connect the equipment as shown in Figure 1 . Select Mode 1, Mode 1B, Subcarrier On, and 8.5 MHz. Adjust the subcarrier level to 0.25 VRMS (50 Ω). Apply standard modulation to d1 and adjust the Mode 1 Unbalance for 80/20 (the d1 sidebands 6 dB above the 8.5 MHz sidebands). Apply standard modulation to d2 and d3 and adjust the Subcarrier Unbalance for 80/20 (the d3 sidebands 6 dB above the d2 sidebands).

5.14.2 Observe the output spectrum and record if the spectrum appears normal for dual QPSK.

5.14.3 Adjust the square-wave modulation for best symmetry and carrier null. Measure and record the level of the J1 sidebands, 8.5 MHz subcarrier, and carrier relative to the unmodulated carrier.

5.15 Phase Stability

5.15.1 Connect the equipment as shown in Figure 1 . Select Mode 1, and Subcarrier Off. With no modulation, measure and record the output noise spectrum using the spectrum analyzer. Set the analyzer bandwidth as narrow as possible and use the 10 Hz video filter. At each frequency from the carrier, record the average level of the signal below the carrier and the bandwidth used.

5.15.1 (Continued)

The input attenuator and IF gain may be adjusted to bring the signal noise out of the analyzer noise floor provided the analyzer is still operating in the linear region, that is a 10 dB change in the input attenuator can be offset by a 10 dB change in the IF gain.

5.15.2 Calculate the noise density relative to the carrier in dB/Hz at each frequency from the carrier. (Conversion to unity bandwidth = 10 log BW.)

5.15.3 Calculate the phase jitter by integrating the noise density spectrum $S\Phi(f)$ from 100 KHz to 10 MHz using the following formulas.

$$(\Delta\Phi)RMS = \left| 2\int_{fa}^{fa+BW} S\Phi(f) \; df \right|^{\frac{1}{2}}$$

$$(\Delta\Phi)p\text{-}p = 6 \; (\Delta\Phi)RMS$$

5.16 <u>Incidental Frequency Modulation</u>

5.16.1 Connect the equipment as shown in Figure 1 . Select Mode 2, and Subcarrier Off. Repeat 5.15.1 and 5.15.2 and calculate the noise density spectrum.

5.16.2 Calculate the incidental FM by integrating the noise density spectrum $S\Phi(f)$ from 2 kHz to 1 MHz using the following formula.

$$(\Delta f)RMS = \left[8\pi^2 \int_{fa}^{fa+BW} f^2 S\Phi(f) \; df \right]^{\frac{1}{2}}$$

5.17 Input Impedance

5.17.1 Connect the equipment as shown in Figure 4 .

5.17.2 Measure and record the input impedance and phase for each of the inputs and frequencies listed.

5.18 AC Power

5.18.1 Connect the equipment as shown in Figure 4 . Measure and record the AC input current and calculate the input power.

5.19 Spurious Output Signals

5.19.1 Connect the equipment as shown in Figure 1 . Select Mode 1, Mode 1A, and Subcarrier Off. With no modulation, measure and record the level and frequency, relative to the carrier, of any signal less than 60 dB below the carrier. Scan plus and minus 2 GHz from the carrier.

5.19.2 Repeat 5.19.1 except select Mode 2, and Subcarrier On. Do not record the 8.5 MHz subcarrier.

5.20 Subcarrier Phase Stability

5.20.1 Connect the equipment as shown in Figure 4 . Select Subcarrier On and 8.5 MHz. With no modulation, measure and record the QPSK Subcarrier Output moise spectrum using the spectrum analyzer. Calculate the noise density as in 5.15.1 and 5.15.2.

5.20.2 Calculate the subcarrier phase jitter from 100Hz to 2 MHz using the formula in 5.15.3.

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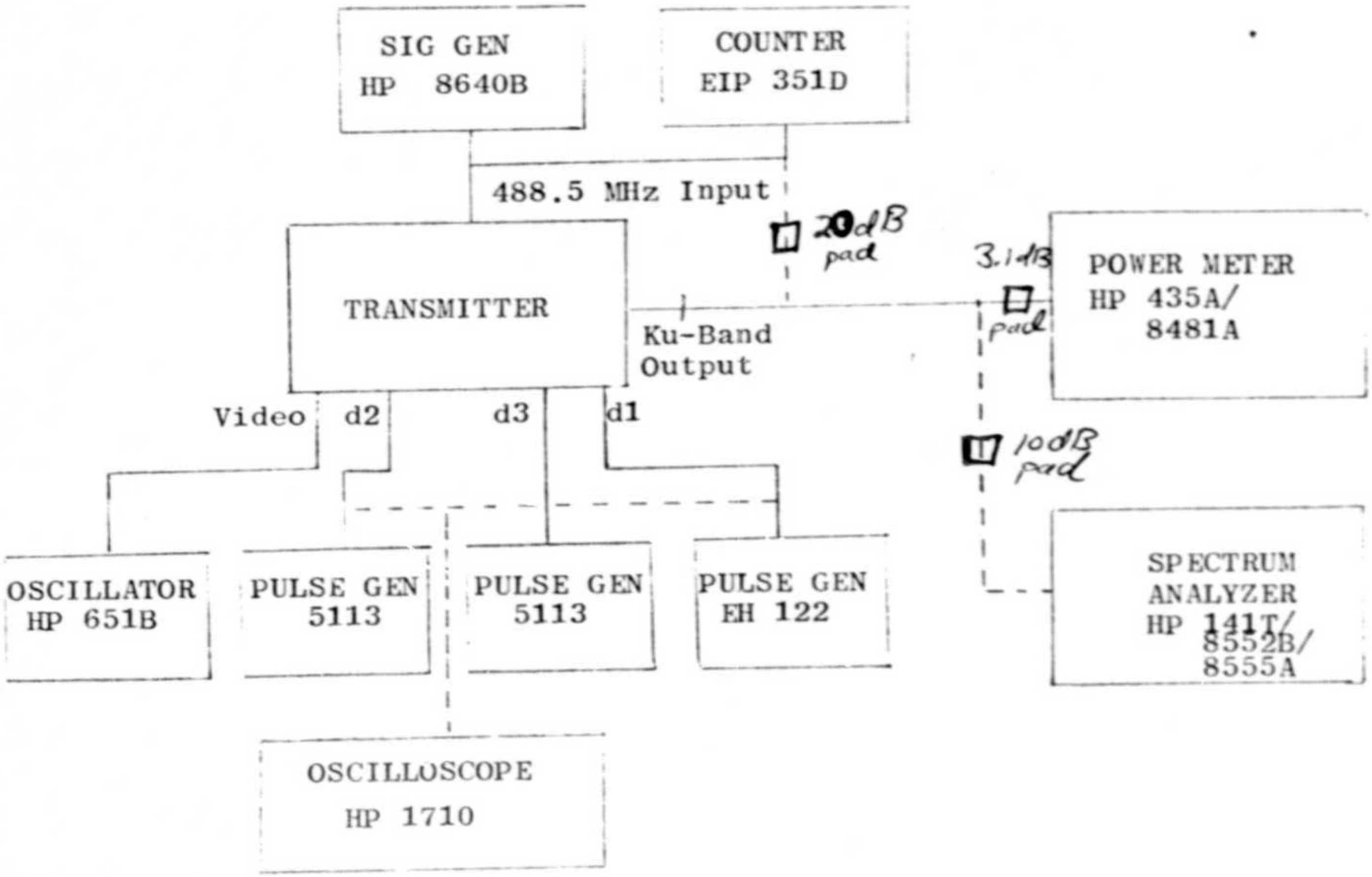

FIGURE 1.
5.1 Frequency and Stability
5.2 RF Bandwidth
5.3 Output Power
5.12 QPSK Data Rate and Deviation
5.13 QPSK Power Unbalance
5.14 Dual QPSK Operation
5.15 Phase Stability
5.16 Incidental FM
5.19 Spurious Output Signals

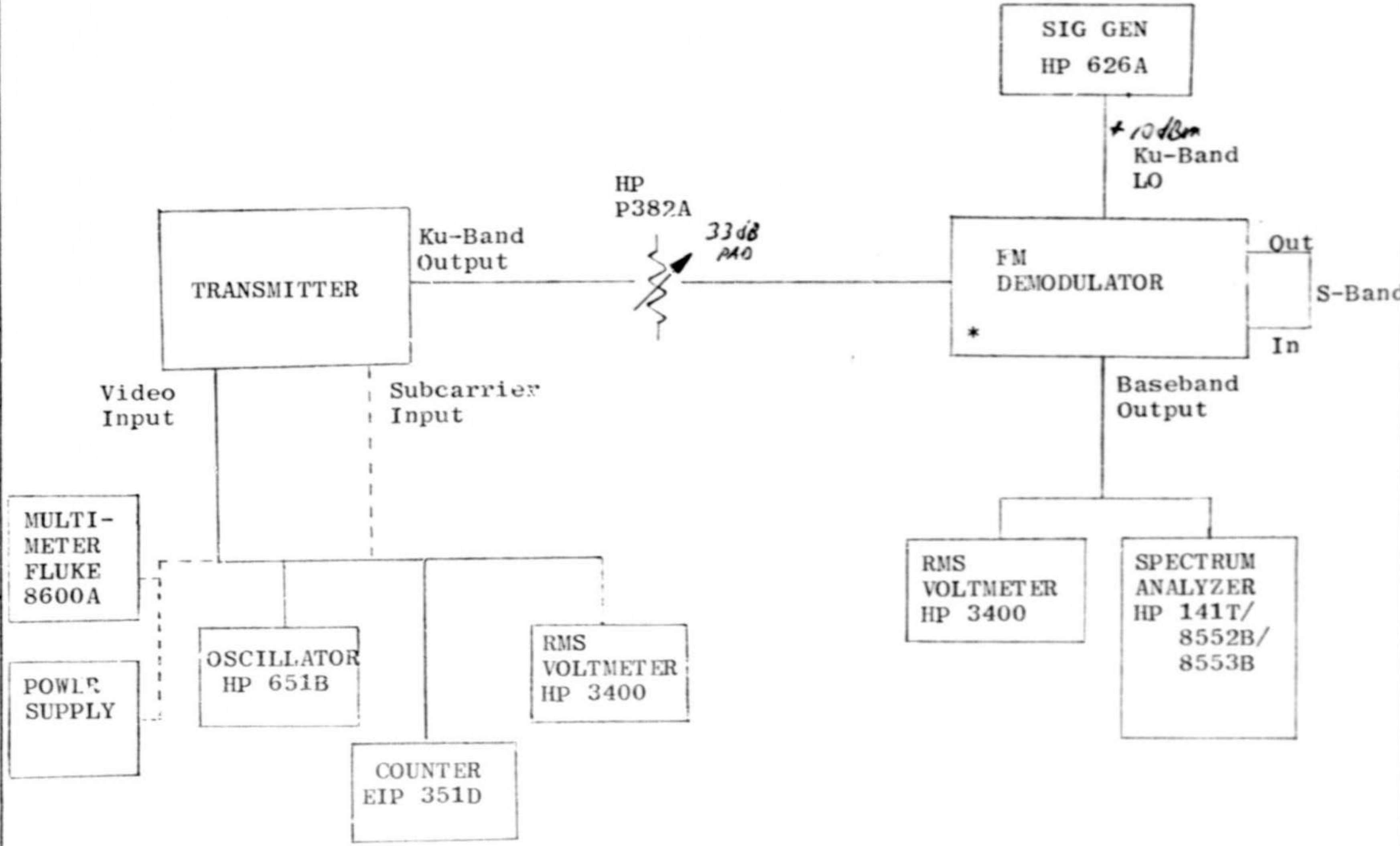

FIGURE 2. 5.4 FM Frequency Response
5.6 FM Deviation Linearity
5.7 FM Harmonic Distortion

*With internal 420 MHz divide by 6

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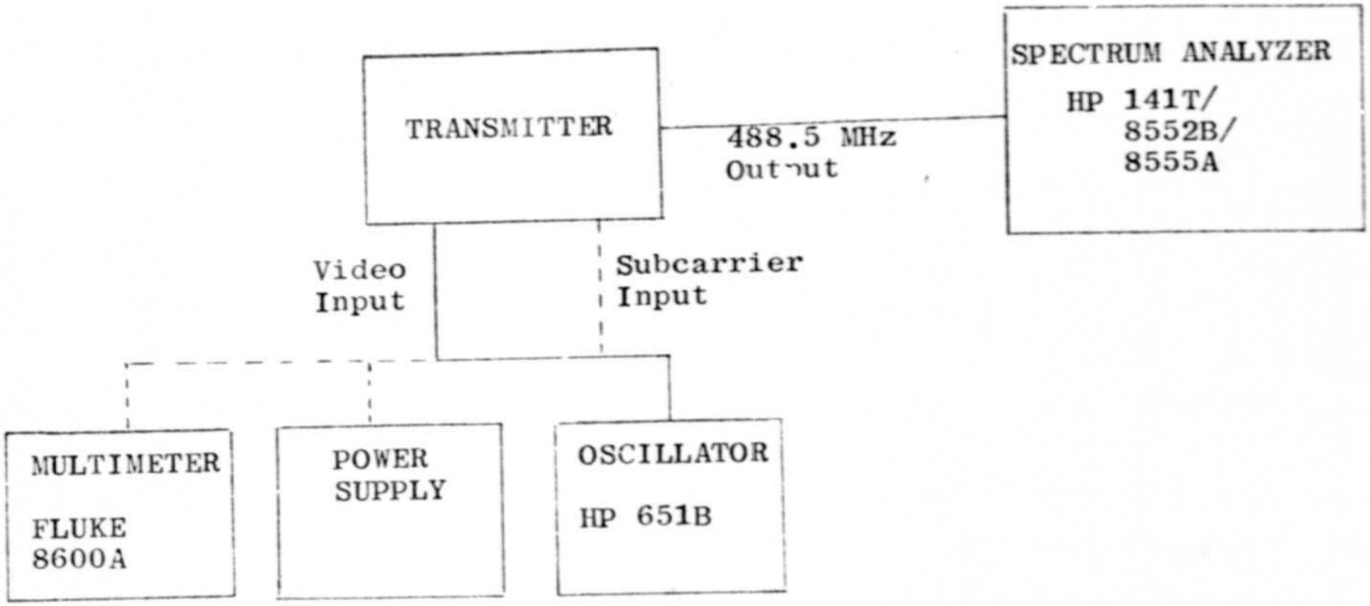

FIGURE 3. 5.5 FM Deviation Sensitivity

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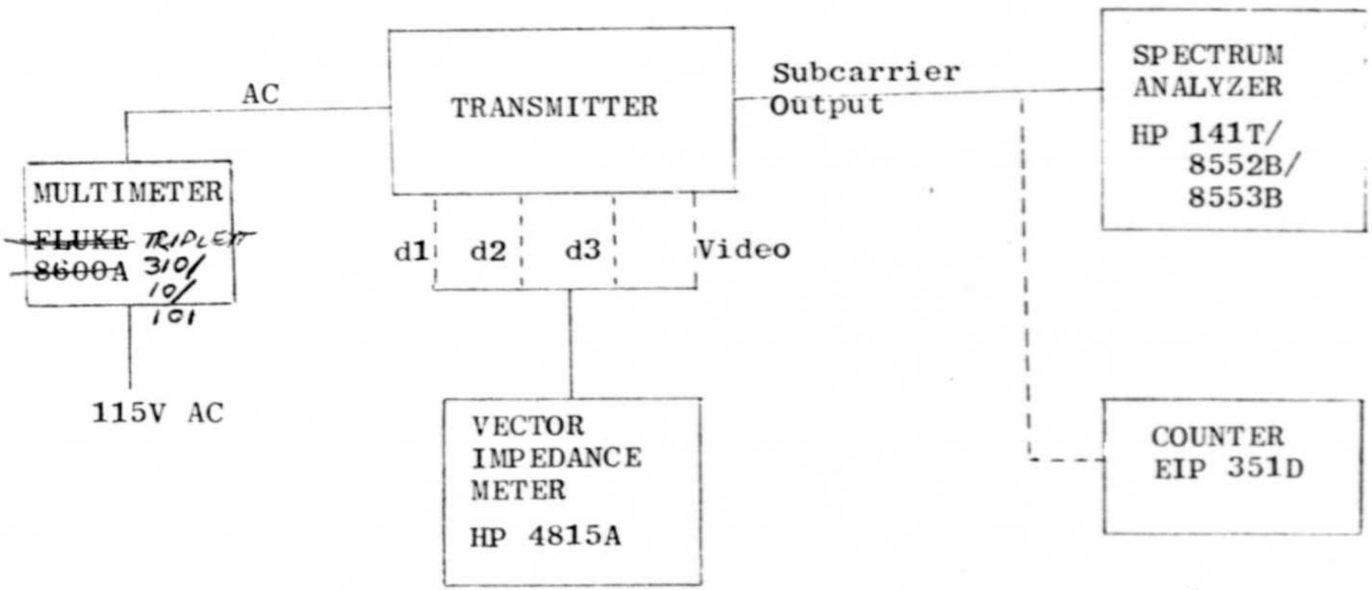

FIGURE 4.
5.8 Subcarrier Frequency
5.17 Input Impedance
5.18 AC Power
5.20 Subcarrier Phase Stability

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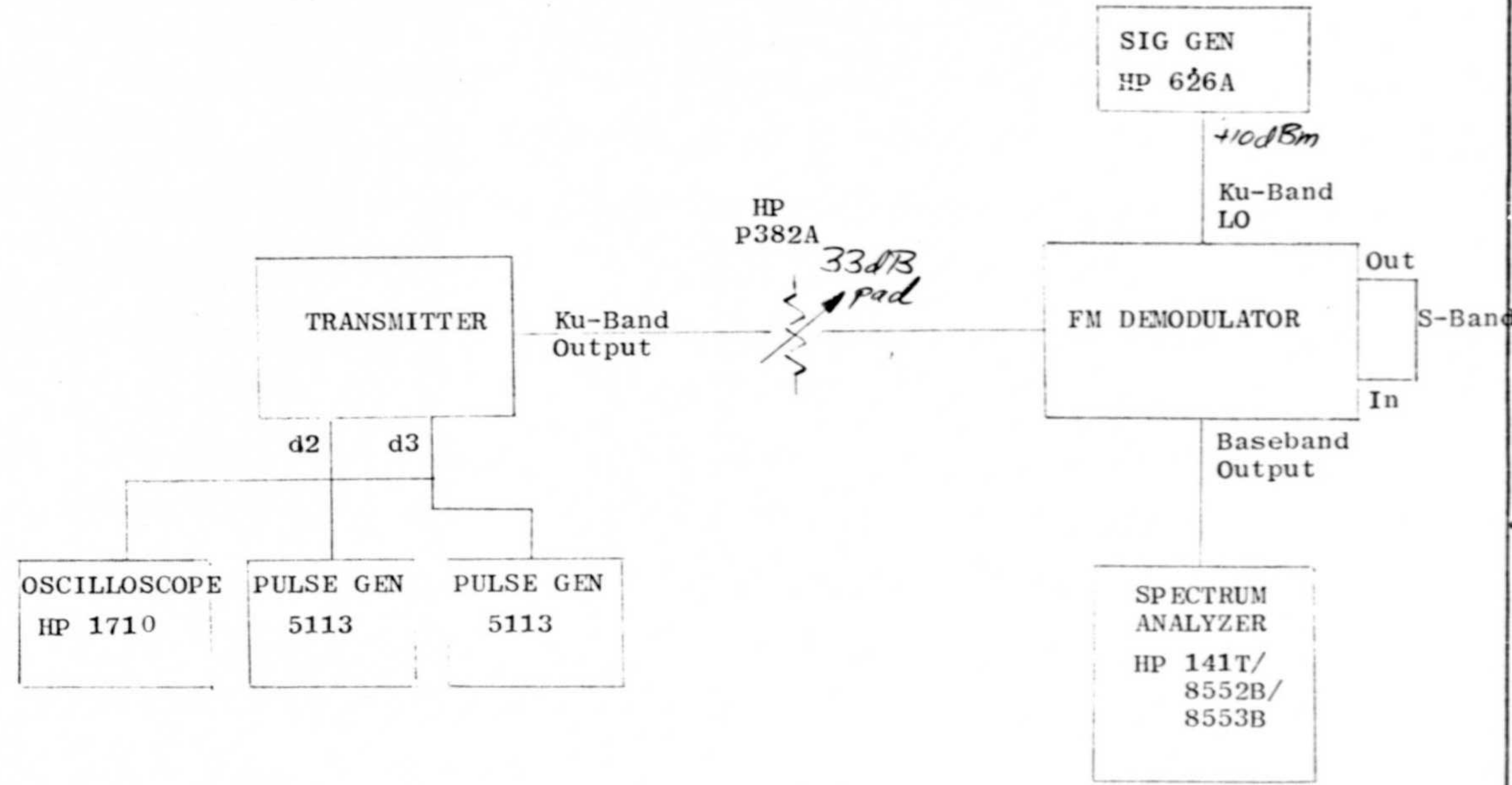

FIGURE 5. 5.9 Subcarrier Data Rate and Deviation
5.10 Subcarrier Power Unbalance

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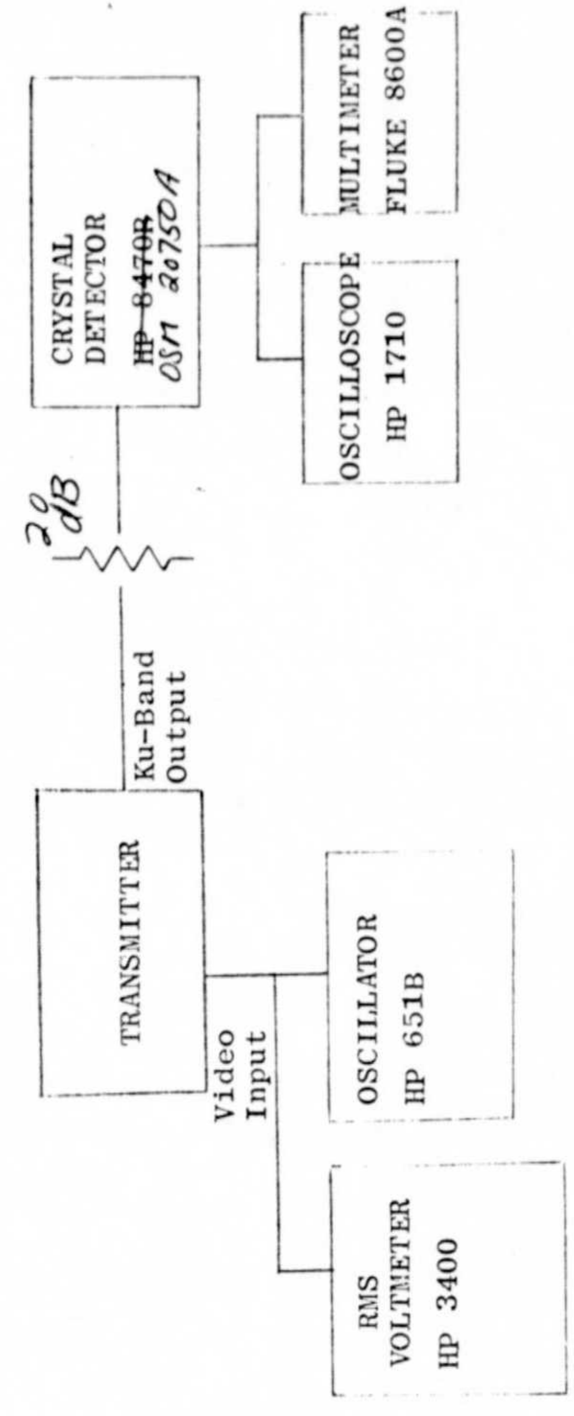

FIGURE 6. 5.11 Incidental AM

Tested By Jeffery L. Marud
Date November 2, 1976

TEST DATA

Para. No.	Parameter	Data	Limits
5.1	Frequency and Stability		
5.1.1	Minimum Frequency	15,002,805 kHz	Information
	Maximum Frequency	15,014,977 kHz	Information
5.1.2	Mode 1 Frequency	15,008,495 kHz	15,008,500 kHz ± 75 kHz
	Mode 2 Frequency	15,008,500 kHz	15,008,500 kHz ± 75 kHz
5.1.3	After one hour		
	Mode 1 Frequency	15,008,495 kHz	15,008,500 kHz ± 75 kHz
	Mode 2 Frequency	15,008,457 kHz	15,008,500 kHz ± 75 kHz
after 6 hours	mode 1 frequency	15,008,495 KHz	
	mode 2 frequency	15,008,504 KHz	
5.2	RF Bandwidth		
5.2.1	Upper 1 dB Frequency	+208.2 MHz	112 MHz Min.
	Lower 1 dB Frequency JLM 11/2/76	-~~208.2~~ 266.0 MHz	112 MHz Min.
	1 dB Bandwidth	474.2 MHz	225 MHz Min.
	Upper 3 dB Frequency	+242.1 MHz	Information
	Lower 3 dB Frequency	-279.7 MHz	Information
	3 dB Bandwidth	521.8 MHz	Information

Tested By J. L. Marud

Date November 1, 1976

Para. No.	Parameter	Data	Limits
5.3	Output Power		
5.3.1	Mode 1A, No Modulation	+20.95 dBm	+19 dBm Min.
5.3.2	Mode 1A, With Modulation	+20.9 dBm	+19 dBm Min.
5.3.3	Mode 1B, With Modulation	+20.9 dBm	+19 dBm Min.
5.3.4	Mode 2, No Modulation	+20.75 dBm	+19 dBm Min.
5.3.5	Mode 2, With Modulation	+20.75 dBm	+19 dBm Min.
5.4	FM Frequency Response		
5.4.1	Video Input		JLM 11/1/76
	500 kHz	0 dB	Reference (-16.7dB)
	100 Hz	+1.0 dB	± 1 dB
	1 kHz	+0.9 dB	± 1 dB
	10 kHz	+0.9 dB	± 1 dB
	100 kHz	+0.7 dB	± 1 dB
	300 kHz	+0.2 dB	± 1 dB
	1 MHz	JLM 11/1/76 -0.3 dB	± 1 dB
	2 MHz	0 dB	± 1 dB
	4.2 MHz	-0.3 dB	± 1 dB
	5 MHz	-1.3 dB	Information
	6 MHz	-3.1 dB	Information
	8.5 MHz	-8.3 dB	Information

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Date November 1, 1976

Para. No.	Parameter		Data	Limits
5.4.2	Subcarrier Input			
		10 MHz	0 dB	Reference (-23.7dB)
		9 MHz	+0.2 dB	Information
		8 MHz	+0.7 dB	Information
		7 MHz	+1.0 dB	Information
		6 MHz	+1.2 dB	Information
		5 MHz	+1.0 dB	Information
		4 MHz	0 dB	Information
		3 MHz	-2.0 dB	Information
		2.64MHz	-3.0 dB	Information
5.5	FM Deviation Sensitivity			
5.5.1	500 kHz, 2.405 Radians			
		Input Voltage	.046 Vrms	Reference
		Sensitivity	18.48 MHz/V	20 MHz/V Nominal
5.5.2	8.5 MHz, 1.202 Radians			
		Input Voltage	.480 Vrms	Reference
		Sensitivity	15.04 MHz/V	Information
5.5.3	Frequency Change for Positive Voltage		✓	Increase
	Frequency Deviation ± 20 MHz		✓	Yes

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Para. No.	Parameter		Data	Limits
5.6	FM Deviation Linearity			
5.6.1	Voltage	Frequency	ΔF	
	+1.0 Vdc	15028.948 MHz	10.232 MHz	Ref.
	+0.5 Vdc	15018.716 MHz	10.221 MHz	Ref.
	0 Vdc	15008.495 MHz	Reference	Ref.
	-0.5 Vdc	14998.205 MHz	10.290 MHz	Ref.
	-1.0 Vdc	14998.132 MHz	10.073 MHz	Ref.
	% Linearity at DC		1.1 %	2% Max.
5.6.2	4 MHz, Video Input			
	Vin	Vout	Sensitivity	
	50 mVrms	13.5 mVrms	.270 V/V	Ref.
	100 mVrms	27.3 mVrms	.273 V/V	Ref.
	200 mVrms	54.2 mVrms	.271 V/V	Ref.
	400 mVrms	110.0 mVrms	.275 V/V	Ref.
	600 mVrms	166.0 mVrms	.277 V/V	Ref.
	800 mVrms	221.0 mVrms	.276 V/V	Ref.
	% Linearity at 4 MHz		1.3 %	2% Max.

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Para. No.	Parameter		Data	Limits
5.6.3 JLM 11/1/76	8.5 ~~10~~ MHz, Subcarrier Input			
	Vin	Vout	Sensitivity	
	50 mVrms	10.4 mVrms	.208 V/V	Ref.
	100 mVrms	21.1 mVrms	.211 V/V	Ref.
	200 mVrms	42.0 mVrms	.210 V/V	Ref.
	400 mVrms	85.2 mVrms	.213 V/V	Ref.
	600 mVrms	131 mVrms	.218 V/V	Ref.
	800 mVrms	176 mVrms	.220 V/V	Ref.
	900 mVrms	199 mVrms	.221 V/V	Ref. 11/1/76
	% Linearity at 8.5 ~~10~~ MHz JLM 11/1/76		3.1 %	Information ~~2% Max.~~ Ron Halterman N.W. Hamilton
5.7	FM Harmonic Distortion			
5.7.1	4 MHz, Video Input			
	Frequency	Relative Level		
	4 MHz	0 dB		Ref.
	8 MHz	-46 dB		Ref.
	12 MHz	-48 dB		Ref.
	16 MHz	-54 ~~-64~~ dB JLM 11/1/76		Ref.
	% Distortion 4 MHz		0.67 %	5% Max.

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Para No.	Parameter		Data	Limits
5.7.2	8.5 ~~10~~ MHz, Subcarrier Input			
JLM 11/1/76	Frequency	Relative Level		
	8.5 ~~10~~ MHz	0 dB		Ref.
	17 ~~20~~ MHz	-36 dB		Ref.
	25.5 ~~30~~ MHz	-52 dB		Ref.
	34 ~~40~~ MHz	>-60 dB		Ref.
		% Distortion 8.5 ~~10~~ MHz JLM 11/1/76	1.61 %	5% Max.
5.8	Subcarrier Frequency			
		8.5 MHz	8,499,684. Hz	8.5 MHz Nom.
		8.75 MHz	8,749,676. Hz	8.75 MHz Nom.
		9.0 MHz	8,999,667. Hz	9.0 MHz Nom.
		9.25 MHz	9,249,658. Hz	9.25 MHz Nom.
		9.5 MHz	9,499,650 Hz	9.5 MHz Nom.
		9.75 MHz	9,749,641 Hz	9.75 MHz Nom.
		10.0 MHz	9,999,633 Hz	10.0 MHz Nom.

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Para. No.	Parameter	Data	Limits
5.9	Subcarrier Data Rate and Deviation		
5.9.2 .	d2 - 192 kHz, d3 - 2 MHz, 50/50		
	Level of Upper d2 J1	-7.2 dB	-7 dB Nom.
	Level of Lower d2 J1	-7.2 dB	-7 dB Nom.
	Level of Upper d3 J1	-7.2 dB	-7 dB Nom.
	Level of Lower d3 J1	-7.2 dB	-7 dB Nom.
	Level of Carrier J0	-37 dB	Information
5.9.3	d2 - 96 kHz, d3-16 kHz, 50/50		
	Level of Upper d2 J1	-7.2 dB	-7 dB Nom.
	Level of Lower d2 J1	-7.2 dB	-7 dB Nom.
	Level of Upper d3 J1	-7.2 dB	-7 dB Nom.
	Level of Lower d3 J1	-7.2 dB	-7 dB Nom.
	Level of Carrier J0	-42 dB	Information
5.10	Subcarrier Power Unbalance		
5.10.2	50/50 Balance Achieved	✓	Yes
5.10.3	90/10 Unbalance Achieved	✓	Yes

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Date November 2, 1976

Para. No.	Parameter	Data		Limits
5.10.4	80/20 Unbalance, d3 - 2 MHz, d2 - 192 kHz			
	Level of Upper d2 J1	-11.2	dB	-11 dB Nom.
	Level of Lower d2 J1	-11.2	dB	-11 dB Nom.
	Level of Upper d3 J1	-5.6	dB	-5 dB Nom.
	Level of Lower d3 J1	-5.5	dB	-5 dB Nom.
	Level of Carrier	-36	dB	Information
5.11	Incidental AM			
5.11.2	DC Output Voltage	.45	Vdc	Ref.
	AC Output Voltage	.004	Vp-p	Ref.
	% AM	0.44	%	5% Max.
5.12	QPSK Data Rate and Deviation			
5.12.2	d1 - 50 MHz, d3 - 2 MHz, 50/50			
	Level of Upper d1 J1	-8	dB	-7 dB Nom.
	Level of Lower d1 J1	-7	dB	-7 dB Nom.
	Level of Upper d3 J1	-7	dB	-7 dB Nom.
	Level of Lower d3 J1	-6.8	dB	-7 dB Nom.
	Level of Carrier J0	-30 ~~-23~~ JLM 11/2/76	dB	Information

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Para. No.	Parameter	Data		Limits
5.10.4	80/20 Unbalance, d3 - 2 MHz, d2 - 192 kHz			
	Level of Upper d2 J1		dB	-11 dB Nom.
	Level of Lower d2 J1		dB	-11 dB Nom.
	Level of Upper d3 J1		dB	-5 dB Nom.
	Level of Lower d3 J1		dB	-5 dB Nom.
	Level of Carrier		dB	Information
5.11	Incidental AM			
5.11.2	DC Output Voltage		Vdc	Ref.
	AC Output Voltage		Vp-p	Ref.
	% AM		%	5% Max.
	RETEST			
5.12	QPSK Data Rate and Deviation			
5.12.2	d1 - 50 MHz, d3 - 2 MHz, 50/50 set at d_1 = 24 MHz			
	Level of Upper d1 J1	-8.0	dB	-7 dB Nom.
	Level of Lower d1 J1	-6.8	dB	-7 dB Nom.
	Level of Upper d3 J1	-6.6	dB	-7 dB Nom.
	Level of Lower d3 J1	-6.4	dB	-7 dB Nom.
	Level of Carrier J0	-34	dB	Information

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Para. No.	Parameter	Data	Limits
5.12.3	d1 - 4 MHz, d3- 16 kHz, 50/50		
	Level of Upper d1 J1	-7.0 dB	-7 dB Nom.
	Level of Lower d1 J1	-6.8 dB	-7 dB Nom.
	Level of Upper d3 J1	-7.0 dB	-7 dB Nom.
	Level of Lower d3 J1	-7.0 dB	-7 dB Nom.
	Level of Carrier J0	-36 dB	Information
5.13	QPSK Power Unbalance		
5.13.2	50/50 Balance Achieved	✓	Yes
5.13.3	90/10 Unbalance Achieved	✓	Yes
5.13.4	80/20 Unbalance, d1 - 50 MHz, d3 - 2 MHz		
	Level of Upper d1 J1	-7.2 dB	-5 dB Nom.
	Level of Lower d1 J1	-5.0 dB	-5 dB Nom.
	Level of Upper d3 J1	-10.4 dB	-11 dB Nom.
	Level of Lower d3 J1	-10.4 dB	-11 dB Nom.
	Level of Carrier	-30 ~~-27~~ dB JLM 11/2/76	Information

RETEST

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Para. No.	Parameter	Data	Limits
5.12.3	d1 - ~~4 MHz~~ 10 MHz, d3- ~~16 kHz~~ 2 MHz, 50/50 set at d_1=24MHz		
	Level of Upper d1 J1	-7.0 dB	-7 dB Nom.
	Level of Lower d1 J1	-6.6 dB	-7 dB Nom.
	Level of Upper d3 J1	-7.4 dB	-7 dB Nom.
	Level of Lower d3 J1	-7.4 dB	-7 dB Nom.
	Level of Carrier J0	-44 dB	Information
5.13	QPSK Power Unbalance		
5.13.2	50/50 Balance Achieved	✓	Yes
5.13.3	90/10 Unbalance Achieved	✓	Yes
5.13.4	80/20 Unbalance, set at 24MHz d1 - 50 MHz, d3 - 2 MHz		
	Level of Upper d1 J1	-6.6 dB	-5 dB Nom.
	Level of Lower d1 J1	-4.2 dB	-5 dB Nom.
	Level of Upper d3 J1	-10.2 dB	-11 dB Nom.
	Level of Lower d3 J1	-10.2 dB	-11 dB Nom.
	Level of Carrier	-32 dB	Information

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Para. No.	Parameter	Data		Limits
5.14	Dual QPSK Operation			
5.14.2	Normal Spectrum for Dual QPSK	✓		Yes
5.14.3	d1 - 50 MHz, 8.5 MHz Subcarrier, 80/20 d3 - 2 MHz, d2 - 192 kHz, 80/20			
	Level of Upper d1 J1	-6.8	dB	-5 dB Nom.
	Level of Lower d1 J1	-4.0	dB	-5 dB Nom.
	Level of Upper d3 J1	-17	dB	-16 dB Nom.
	Level of Lower d3 J1	-16	dB	-16 dB Nom.
	Level of Upper d2 J1	-22	dB	-22 dB Nom.
	Level of Lower d2 J1 ~~X~~ JLM 11/2/76	-22	dB	-22 dB Nom.
	Level of 8.5 MHz J0	~~-35~~ -44 ~~-29~~	dB JLM 11/2/76	Information
	Level of Carrier J0	-29	dB	Information

RETEST

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Date November 3, 1976

Para. No.	Parameter	Data	Limits
5.14	Dual QPSK Operation		
5.14.2	Normal Spectrum for Dual QPSK	✓	Yes
5.14.3	d1 - 50 MHz, 8.5 MHz Subcarrier, 80/20 d3 - 2 MHz, d2 - 192 kHz, 80/20	set at d1 - 24 MHz	
	Level of Upper d1 J1	-6.2 dB	-5 dB Nom.
	Level of Lower d1 J1	-3.6 dB	-5 dB Nom.
	Level of Upper d3 J1	-16 dB	-16 dB Nom.
	Level of Lower d3 J1	-16 dB	-16 dB Nom.
	Level of Upper d2 J1	-22 dB	-22 dB Nom.
	Level of Lower d2 J1	-22 dB	-22 dB Nom.
	Level of 8.5 MHz J0	-38 dB	Information
	Level of Carrier J0	-30 dB	Information

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Para. No.	Parameter	Data	Limits
5.15.	Phase Stability		
5.15.1,2	Mode 1		

Δ Freq.	BW	dB/Carrier	dB/Hz	Limits
2 kHz	0.3 kHz	-53 dB	77.8	Ref.
4 kHz	0.3 kHz	-53 dB	77.8	Ref.
10 kHz	0.3 kHz	-57 dB	81.8	Ref.
20 kHz	1.0 kHz	-65 dB	95	Ref.
40 kHz	1.0 kHz	-75 dB	105	Ref.
100 kHz	3.0 kHz	-75 dB	109.8	Ref.
200 kHz	3.0 kHz	-78 dB	112.8	Ref.
400 kHz	10.0 kHz	-78 dB	118	Ref.
1 MHz	10.0 kHz	-81 dB	121	Ref.
2 MHz	30.0 kHz	-78 dB	122.8	Ref.
4 MHz	30.0 kHz	-78 dB	122.8	Ref.
10 MHz	30.0 kHz	-78 dB	122.8	Ref.

Para. No.	Parameter	Data	Limits
5.15.3	Phase Jitter, 100 kHz to 10 MHz	0.21 ° RMS	Ref.
		1.26 ° p-p	5° p-p max.
	2 KHz TO 10MHz	0.88 °RMS	INFORMATION

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Para. No.	Parameter		Data	Limits
5.16	**Incidental Frequency Modulation**			
5.16.1	Mode 2			

Δ Freq.	BW	dB/Carrier	dB/Hz	Limits
2 kHz	0.3 kHz	-24 dB	48.8	Ref.
4 kHz	0.3 kHz	-30 dB	54.8	Ref.
10 kHz	0.3 kHz	-38 dB	62.8	Ref.
20 kHz	0.3 kHz	-45 dB	69.8	Ref.
40 kHz	1.0 kHz	-50 dB	80.0	Ref.
100 kHz	1.0 kHz	-70 dB	100.0	Ref.
200 kHz	3.0 kHz	-74 dB	108.8	Ref.
400 kHz	3.0 kHz	-81 dB	115.8	Ref.
1 MHz	10.0 kHz	-80 dB	120.0	Ref.

5.16.2 Incidental FM, 2 kHz to 1 MHz 2.07 kHz RMS 5 kHz RMS Max.

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Date November 2, 1976

Para. No.	Parameter		Data		Limits
5.17	Input Impedances				
5.17.2	Video	DC	57.11 Ω		50Ω Nom.
		4.2 MHz	48 Ω	∠-4°	50Ω Nom.
	d3 - Mode 2, 1B	2 MHz	51 Ω	∠+1°	50Ω Nom.
	d3 - Mode 1A	2 MHz	51 Ω	∠+1°	50Ω Nom.
	d2	500 kHz	51 Ω	∠+1°	50Ω Nom.
	d1	~~50 MHz~~	101.42 Ω	DC	100Ω Nom.
5.18	AC Power				
5.18.1	Input Current		0.72 Amps		Ref.
	Input Power		82.8 Watts		Information

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Para. No.	Parameter		Data	Limits
5.19	Spurious Output Signals			
5.19.1	Mode 1	Freq.	dB Below Carrier	
		f_c + 120MHz	60	Information
		f_c - 120MHz	60	Information
				Information
				Information
				Information
				Information
				Information
				Information
				Information
5.19.2	Mode 2			
		f_c+244MHz	55	Information
		f_c-244MHz	54	Information
				Information
				Information
				Information
				Information
				Information

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Para. No.	Parameter	Data	Limits
5.20	Subcarrier Phase Stability		

5.20.1

Δ Freq.	BW	dB/Carrier	dB/Hz	
100 Hz	10 Hz	-55 dB	-65	Ref.
200 Hz	10 Hz	-55 dB	-65	Ref.
400 Hz	30 Hz	-60 dB	-74.8	Ref.
1 kHz	30 Hz	-60 dB	-74.8	Ref.
2 kHz	100 Hz	-55 dB	-75	Ref.
4 kHz	100 Hz	-55 dB	-75	Ref.
10 kHz	300 Hz	-53 dB	-77.8	Ref.
20 kHz	300 Hz	-60 dB	-84.8	Ref.
40 kHz	300 Hz	-72 dB	-96.8	Ref.
100 kHz	1.0 kHz	-83 dB	-113	Ref.
200 kHz	1.0 kHz	-95 dB	-125	Ref.
400 kHz	3.0 kHz	-103 dB	-137.8	Ref.
1 MHz	3.0 kHz	-106 dB	-140.8	Ref.
2 MHz	10.0 kHz	-103 dB	-143	Ref.

5.20.2 Phase Jitter, 100 Hz to 2 MHz 1.6 ° RMS Information

EQUIPMENT	MANUFACTURER/MODEL	S/N or ASSET.	CALIBRATION
AM-FM Signal Generator	HP 8640B opt. 002	G 03712	1/31/77
Test Oscillator	HP 651B	G 00204	1/31/77
Signal Generator	HP 626A	G106884	1/31/77
Signal Generator	HP 608C	G104811	1/31/77
Pulse Generator	Data Dynamics 5113	G 01435	1/31/77
Pulse Generator	Data Dynamics 5113	G01849	1/31/77
Pulse Generator	EH 122	G105250	1/31/77
RMS Voltmeter	HP 3400	G03638	1/28/77
RMS Voltmeter	HP 3400	G01597	1/28/77
Power Meter	HP 435A	G05397	1/28/77
Power Sensor	HP 8481A	G05397	1/28/77
Spectrum Analyzer	HP 141T	G02419	1/28/77
Analyzer, RF Tuning Section	HP 8555A	G03605	1/31/77
Analyzer, IF Section	HP 8552B	G05531	1/28/77
Analyzer, Tuning Section	HP 8553B	G02724	1/28/77
Frequency Counter	EIP 351D	G05380	1/31/77
Vector Impedance Meter	HP 4815A	G02734	1/31/77
Crystal Detector	HP 8470B	Not Used	—
Digital Multimeter	Fluke 8600A	G03849	1/28/77
Oscilloscope	HP 1710	G03867	1/28/77
2 GHz High Pass Filter	Microlab FH 2000	Not Used	—
Waveguide to SMA Adapter	OSM 20187 AJ	S/N 5554	—
FM Demodulator	Motorola 01-P05461J	NASA JSC 106473	—
Variable Attenuator	HP P382A	Not Used	—

Substitute or Additional Equipment

Triplett Model 310 with model 10 adapter and model 101 adapter		TES-365	—
Crystal Detector	OSM 20750A	S/N 0236	—
Frequency Counter	HP 5303B	G02600	1/28/77

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